Precipitation, record amounts—Continued

PENSACOLA

	January	February	March	April	May	June	July	August	September	October	November	December
5 minutes	0.51	0.61	0.59	0.64	0.57	0.46	0.53	0.60	0.57	0.78	0.65	0.62
Year	1929	1912	1912	1912	1915	1916	1924	1915	1920	1909	1914	1916
10 minutes	0.71	0.94	0.97	1.15	1.01	0.79	0.87	1.13	0.99	1.55	1.16	0.92
Year	1918	1912	1912	1912	1915	1916	1908	1915	1920	1909	1914	1916
15 minutes	0.80	0.96	1.19	1.49	1.31	1.10	1.20	1.27	1.37	2.27	1.64	1.04
Year	1918	1912	1912	1912	1915	1916	1906	1915	1920	1909	1914	1916
30 minutes	1.07	1.30	1.55	2.10	1.97	1.72	2.17	1.90	* 2.25	3.63	2.20	1.17
Year	1903	1926	1912	1919	1915	1916	1907	1916	1906	1909	1914	1909
1 hour	1.64	1.48	3.01	3.10	2.43	2.23	3.33	3.01	3.73	4.27	3.17	1.59
Year	1903	1926	1912	1919	1915	1916	1907	1922	* 1906	1909	1903	1905
2 hours	2.58	1.84	3.98	4.38	2.62	2.43	3.96	4.71	* 6.14	4.82	5.03	2.15
Year	1903	1926	1912	1919	1915	1916	1907	1919	1906	1909	1903	1911
24 hours	3.52	5.05	8.32	8.91	5.63	10.70	5.01	9.60	8.56	7.30	7.66	4.32
Year	1881	1881	1913	1919	1915	1887	1896	1919	T.D. 1926	1923	1914	1911
1 month	9.97	12.53	13.37	13.90	9.92	14.11	17.90	18.52	18.65	14.66	14.82	11.06

* 2 days after tropical disturbance.

Precipation, record amounts—Continued

TAMPA

	January	February	March	April	May	June	July	August	September	October	November	December
5 minutes	0.47	0.66	0.55	0.52	0.70	1.00	0.54	0.59	1.05	0.57	0.44	0.42
Year	1904	1927	1900	1928	1930	1900	1920	1906	1924	1928	1903	1907
10 minutes	0.65	1.05	1.05	0.79	1.17	1.50	0.87	1.15	1.66	0.90	0.69	0.82
Year	1904	1927	1900	1921	1930	1900	1920	1898	1924	1928	1911	1907
15 minutes	0.73	1.26	1.40	0.98	1.58	1.90	1.12	1.60	2.03	0.98	0.82	0.94
Year	1909	1927	1900	1921	1930	1900	1910	1898	1924	1928	1911	1907
30 minutes	0.93	1.96	1.50	1.73	2.00	2.45	1.86	2.72	2.44	1.26	1.31	1.33
Year	1912	1927	1900	1920	1930	1900	1920	1925	1924	1902	1925	1907
1 hour	1.28	2.17	1.65	2.56	2.74	3.65	2.61	4.01	2.76	1.52	1.55	1.98
Year	1904	1927	1900	1920	1902	1930	1920	1925	1924	1923	1925	1907
2 hours	1.60	2.40	2.49	2.76	3.04	4.46	2.84	4.59	3.22	2.21	2.04	2.76
Year	1904	1927	1930	1920	1902	1930	1920	1925	1907	1923	1925	1907
24 hours	3.58	4.06	5.62	[1] 2.94	3.55	5.54	5.53	5.04	6.56	T.D. 6.48	4.18	3.93
Year	1914	1902	1930	1930	1923	1909	1925	1915	1897	1921	1916	1907
Month	6.73	6.27	9.87	8.04	9.41	13.47	15.53	17.83	18.93	10.33	4.85	7.36

[1] Amount exceeded this year, 1931, —4.25.

EDWARD H. SMITH ON THE SCIENTIFIC RESULTS OF THE MARION EXPEDITION OF 1928, TO DAVIS STRAIT AND BAFFIN LAND

By W. F. McDONALD

[Weather Bureau, Washington, December, 1931]

Since its establishment in 1913 as a result of the *Titanic* disaster, the international ice patrol has been collecting scientific data on the oceanography of the ice regions of the North Atlantic as an adjunct to its primary work of scouting for bergs and warning shipping of dangerous ice movements.

Lieut. Edward H. Smith has for more than 10 years been concerned with the scientific aspects of the ice-patrol work. In his latest monograph on scientific results of the intensive oceanographical survey conducted by the Coast Guard cutter *Marion* during the 1928 patrol season, he sums up not only the fruits of his own extensive observations and researches but also includes a comprehensive survey of world literature on the subject of polar ice and ice movements.

The work, published as Part 3 of Coast Guard Bulletin No. 19, includes original contributions by Lieutenant Smith toward the solution of such complex questions as the following: In what manner does ice from the Polar Basin, Baffin Bay, and Hudson Bay, contribute to supply the North Atlantic? What is the annual variation in ice limits and number of icebergs? In what proportions do wind and current enter to control the drift of icebergs? Is the effect of ice melting in northern waters a factor of importance in the main system of oceanic circulations? What meteorological and other factors govern the probable seasonal prevalence of ice along the trans-Atlantic steamer routes?

The chief source of the icebergs that drift to the steamer lanes is conclusively demonstrated to be the great Greenland glaciers of the Baffin Bay region. Major productivity of bergs is confined to the 300-mile stretch of west Greenland coast, central on the seventieth parallel of latitude, and comprising Northeast and Disko Bays, but a lag of some months and in some cases years intervenes between the calving of bergs and their final disappearance in the waters off Newfoundland. The character of the weather during the life of a berg has much to do with determining the route over which it drifts, and also its rate of melting.

Lieutenant Smith demonstrates that the quantity and disposition of the great sheets of relatively thin ice, classed as "pack ice" is a most important factor in the number of bergs which reach the vicinity of the steamer lanes. Sheet ice forms annually to an estimated average thickness of six feet over an area believed to be between 400,000 and 500,000 square miles contributory to the northwestern Atlantic. The amount of pack ice formed depends directly upon the severity of the winter temperatures, and perhaps less directly upon other meteorological conditions (such as storminess) which affect the set of the circulations and the mixing of water masses.

Being sheetlike in structure, pack ice responds readily in its movement to wind; in this respect it is perhaps the most responsive of all oceanographic phenomena to meteorological conditions.

Icebergs are not so responsive to wind, because the exposed portion is only a small fraction of the total mass. However, the shape of the berg appears to be quite important in this connection since its manner of drift seems to depend on the ratio of extreme height above water to the maximum depth of immersion rather than upon the relative masses above and below the water line.

The average ratio of height above water to draft in the case of the usual type of Greenland bergs is reported to be much less than commonly supposed. The ratio of 1 to 3 is common in the earlier stages and as low as 1 to 1 has been measured in certain horned or winged disintegration forms.

It is apparent from these and other analogous facts that in general the drift of icebergs is more subject to the influence of sea currents at some depth than to the pressure of wind. Smith adduces quantitative data in respect to the relative importance of wind and current and his conclusion is best stated in his own language, as follows: "The deeper draft bergs common to Baffin Bay are moved only 4 miles a day by wind, force 6 to 7. In the case of the deeper bergs drifting within the bounds of an ocean current such as the Labrador current, small influences due to frequently shifting winds are masked by simultaneous movements imparted by the much steadier and more enduring slope current."

The variation in drift, to the right of the wind direction, under the Ekman effect, is stressed, and it is stated that "During a period of even moderate to fresh winds the shoaler berg will drift about 14° to the right of the heavier ones in 24 hours and leave the latter some 4 miles astern, the bergs alternately separating and congregating with the play of the winds." This shows conclusively the major influence of the stable ocean currents rather than the winds, in producing the steady travel of bergs over long periods of time.

Strong evidence supports the conclusion that the amount of pack ice moving down the Labrador coast to the Newfoundland banks is a major factor in the arrival of icebergs in the same vicinity. It seems that the ice pack covering the shallower coastal waters fends off the icebergs and keeps them moving southward; contrariwise, with coastal waters free from pack there is stranding and melting of bergs before they attain the region of the Grand Banks. The year 1928 was marked by a great scarcity of pack ice and also of bergs off Newfoundland, while a close estimate in that year indicated that over 700 icebergs were stranded between Belle Isle and Hudson Strait.

Significant correlation is found between the winter atmospheric pressure gradient (December to March), Ivigtut to Belle Isle, and the spring crop of icebergs south of Newfoundland. Forty-seven years of records enter into the computation. Other significant meteorological factors were found, including mainly the pressure anomaly over Iceland, December to March, and the pressure gradient, October to January, between Iceland and Bergen. The combination of these factors indicates that an excess of pressure in winter over Iceland and southern Greenland, especially in December and January, is unfavorable to the movement of icebergs southward toward the Grand Banks and the steamer lanes in the next spring; the opposite relation is unmistakable in its correlation with a greater number of bergs than normal, but shows a smaller correlation coefficient than that between excessive pressure anomalies and poor iceberg years. This indicates the influence of other more obscure factors, such as variations in air and water temperatures in the far north; variations in precipitation, and perhaps sporadic phenomena such as loosening of ice jams in the Arctic Archipelago or Smith Sound, in releasing unusual quantities of bergs.

The *Marion* oceanographic program included a number of surveys to secure basic data for estimation of the dynamic gradients underlying current drifts and variations. The results are of considerable interest to the meteorologist, in revealing the presence of a dynamic cyclone in the sea where the Labrador current meets the Gulf Stream near the "Tail of the Grand Banks," about 49° W. longitude, and 42° N. latitude.

As might be expected this cyclonic circulation in the ocean currents is of much smaller extent though more persistent than the usual atmospheric cyclone. In discussing this peculiar local movement, which, it is worth emphasizing, occurs in the region where the temperature gradient is at a maximum between the cold outflow from the Labrador current, and the warm flow of the Gulf Stream, Smith says:

> This "low," covering an area of over 2,000 square miles, was first discovered by chance in 1921 by following an iceberg as it made the circuit. In 1926 the "low," apparently similar in character to an atmospheric cyclonic depression, was accurately charted by several successive dynamic surveys, prevailing throughout the season. It was present also in April, 1927, but disappeared early that May * * *. In general, the agreement between the berg tracks that have actually been followed and the gradient currents for the same periods, respectively, is so close as to indicate that dynamic projections of this sort may be used as a basis for predicting the tracks that individual bergs are most likely to follow. * * *
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> The current maps obtained by dynamic surveys have been found to remain reliable for a period of 7 to 15 days around the Grand Banks. Minor fluctuations of short duration have often been observed, however, especially along the boundary of mixed waters and the Gulf Stream. Such swirls or vortices appear to be secondary superficial tongues 5 to 10 miles in width and several times that in length and the tracks of icebergs, especially the small shallow-draft ones, are often modified by such departures.
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> Occasionally icebergs survive relatively long periods, even when floating in Atlantic Ocean water of high temperature, and they may then make phenomenal journeys. * * * These drifts, however, do not indicate a direct extension of the Labrador current into low latitudes but simply that the bergs in question have been caught up in oceanic vortices that are continually forming over the Atlantic Basin, in which the ice is borne southward instead of following the normal drift. * * * As a matter of fact, it is unusual for a berg to drift south of the fortieth parallel of latitude in the western North Atlantic, the record for the past 20 years showing only 1 such occurrence every 1 to 3 years.

In a footnote, the author adds: "It has already been pointed out that the outlet for icebergs departing on extra southerly drifts is noticeably confined between meridians 46 to 50, almost directly south of the Grand Banks."

The observations of icebergs and ice-pack movement past Newfoundland and along the Grand Banks rather conclusively disprove the existence of a branch of the Labrador current setting steadily westward or southwestward from Cape Race. The Gulf of St. Lawrence does, however, discharge pack ice and icy waters past Nova Scotia, and the supply of cold water from this source, plus the natural cooling processes, seem ample to account for the maintenance of a cold zone between the Gulf Stream and the New England coast.

The study concludes with a most interesting and valuable discussion of the effect of northern ice on the temperature and circulation of the waters of the North Atlantic. Beginning with the estimate that more than 1,000 cubic miles of ice are annually transformed from solid to liquid in the northern North Atlantic along a front from Spitzbergen to Labrador, there is an examination of the propositions, which some students have advanced, that the heat required to melt this enormous quantity of ice produces the chilling effect "which initiates great downpourings of cold bottom waters" and thus serves as the "main energizing agent responsible for the Atlantic circulation." Lieutenant Smith examines these propositions with quantitative estimates of the factors involved.

Of the sea ice present in the Davis Strait-Baffin Bay region (which embodies the major iceberg production in the northern hemisphere) the glacial ice comprising the bergs is only 2 per cent. The remainder represents ice frozen from sea water, in which case the release of latent heat "produces a material retardation in the freezing process, and this phenomenon, moreover, is of such magnitude in the polar regions that it tends to stabilize the seasonal fluctuations."

It is clear from the small ratio of icebergs to total ice, that the discharge of glacial ice is of no practical moment in the cooling of sea water. Further, the fact that in vertical dimension, total sea ice is only about one-thousandth of the mean depth of the Atlantic shows how superficial the ice processes must be. Melting produces relatively light thaw water, which stratifies stably at the surface and creates a situation in which solar warming of the summer season is largely accumulated as a heat reserve in the upper layer of only 20 to 40 meters depth, underlaid by a tremendous mass of cold water representing the net accumulations from winter cooling by radiation, within the great area of the Polar Basin and its adjacent waters.

The radiation absorbed in the areas of open water, which is thus largely confined to the shallow top layer, is readily lost, with the onset of winter, and is not adequately compensated by the latent heat released by freezing of new ice. These and other considerations lead to a quantitative estimate that only about 10 per cent of the total cooling received by the North Atlantic in the southward discharge of cold currents can be attributed to the cooling effect of ice melting. The final summations are best stated in the author's own words, as follows:

Obviously, the low temperature character of the Labrador and east Greenland currents is not due to the melting ice with which these streams are charged in spring and summer. These ocean currents are cold because of the small amount of absorption of solar radiation at the earth's surface in the polar regions. * * *

It is interesting to note in the quantitative treatment of these northern seas phenomena that the cooling factors, viz, chilling by the winter atmosphere, ice melting, snowfall, and evaporation, when totaled, outweigh the solar warming of summer. * * * The great major effect therefore tending to maintain more or less of a constant counterbalance over a long period is the warm currents from the Tropics. * * *

Perhaps it is because the ice catches the eye and the imagination more than do the coastal water masses with which it is ordinarily associated that its relative importance in the picture of oceanographic circulation has been overemphasized. The regional difference of density between coastal and oceanic waters is the main spring for the convectional currents. The winds also, by their direct frictional effect, combined with the presence of the coast lines or other hindrances, develop significant slope currents. The transition zones, i. e., the continental edges, and the (submarine) ridges, mark the belts of greatest energy, and in the sea energy is synonomous with current.

Ice melting over the North American and east Greenland shelves helps to accentuate the contrasts between coastal and oceanic waters, thereby intensifying the currents, but emphatically it is not the main cause of propulsion nor is it even a necessary attribute thereof.

The bulletin is amply illustrated with diagrams, charts, and pictures but the lack of a good map of the north polar regions, fully identifying the geographic features to which frequent and repeated reference is made, is the one point of inadequacy found in this interesting and valuable contribution to oceanography.

CLOUD FLIGHTS [1]

By A. LOHR

[Hamburg, Germany]

[Translated by Eric R. Miller and abstracted by L. T. Samuels]

The daily airplane observation flights made by the Deutsche Seewarte at the Fuhlsbüttel airport have been classified and those made at times when the airplane passed through a solid cloud layer, i. e., when during both the ascent and the descent the earth was entirely cut off from view, have been segregated. The percentages of such flights of the total during 1928 and 1929 were 46 and 44, respectively.

The following features are mentioned:

If the lower boundary of a solid cloud sheet consists of Fr. St. or Fr. Nb., then there is no great danger in emerging from the cloud in descent as the turbulence existing near the ground, indicated by the Fr. St. and Fr. Nb., results in the partial dissipation of the lower boundary of low cloud forms. The Fr. St. or Fr. Nb. very frequently extends to within 100 meters of the ground and has a vertical thickness of 100 to 300 meters. With Nb. there follows immediately the transition to the continuous main cloud sheet, whereas with St. there is often observed a separate thick, clear, intermediate stratum between the Fr. St. and the dense continuous St. A far more dangerous condition to aviation occurs when the Fr. St. or Fr. Nb., stratum is absent and the base of the main cloud sheet is only 100 to 150 meters above ground. In such cases the cloud layer may often reach the ground in some places.

The form of the upper surface of the cloud sheet is varied. On many days it appears like an entirely plane surface. At such times a strong temperature inversion always exists at its level. When a heavy accumulation of haze prevails over the upper cloud surface, then from a greater height the cloud layer appears as an absolutely smooth surface. Occasionally the upper surface is slightly rippled and shows an irregular structure, while at other times it is regularly waved. The wave crests may extend lengthwise for a kilometer but are never very high. All of the types of clouds thus far referred to are an indication of little or no vertical motion within the layer.

Turbulence rolls such as occur in a St. Cu. layer are fundamentally different from the above-mentioned wave structure. In summer, it frequently happens that a horizontal upper surface is overtopped by single Cu. heads which indicate local and narrowly limited overheating. Such Cu. forms are frequently surrounded by cloud-free holes in which descending air creates rather strong "falling" bumpiness.

The cumuli of convection exhibit a more stupendous form than the cumuli of turbulence. The former rise most steeply into the heavens and when illuminated by the sun conjure up marvelous pictures by their rugged lights and shadows. From them, occasionally, thunderheads rise upward to 6,000 meters altitude. The strong bumpiness around the edge of such thunderheads is well known. Flying through them can not be sufficiently warned against. Within such clouds vertical gusts reaching from 10 to 15 meters per second are encountered, while below an ordinary cumulus these velocities usually reach only 2 to 4 meters per second, the latter being very successfully employed in early gliding experiments.

In connection with the vertical currents in upwelling Cu. heads there occur the "caps" over the Cu., the latter being composed mostly of ice particles. Often the raised St. layers that are penetrated by the thunderhead spread

[1] Meteorologische Zeitschrift, September, 1930.